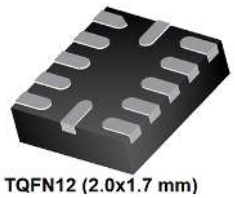
400 mA nano-quiescent synchronous step-down converter with digital voltage selection, Power Good and load switch



TQFN12 (2.0x1.7 mm)

Features

- 500 nA input quiescent current at V_{IN} = 3.6 V (not switching)
- 92% typical efficiency at 10 mA load (V_{IN} = 3.6 V, V_{OUT} = 2.5 V)
- 100% duty cycle
- 1.8 V to 5.5 V input operating range
- Undervoltage lockout: 1.57 V (V_{IN} falling, typ.)
- Up to 400 mA output current capability
- Low power control operation for the best efficiency
- Embedded soft-start circuit
- Tiny external components: L = 2.2 µH typ.
- Selectable output voltages: 1.6 V to 3.3 V
- Output voltage Power Good
- ±1.5% output voltage accuracy (V_{OUT}, T_A = 25 °C)
- Dynamic output voltage selection (D0, D1 and D2)
- Load switch controlled by AUX input
- Available in TQFN12 package

Applications

- Wearable applications
- Personal tracking monitors
- Smart watches, sport bands
- Energy harvesting, wireless sensors
- Wearable and fitness accessories
- Industrial sensors, portable low power devices
- Single cell Li-Ion battery applications
- Bluetooth® Low Energy
- Zigbee

Product status link
ST1PS03

Description

The ST1PS03 is a nano-quiescent miniaturized synchronous step-down converter, which is able to provide up to 400 mA output current with an input voltage ranging from 1.8 V to 5.5 V. This converter is specifically designed for applications where high efficiency, PCB size and thickness are the key factors.

The output voltage can be set using three digital control inputs, a V_{OUT} from 1.6 V to 3.3 V can be dynamically selected. Thanks to the enhanced PCC (peak current control) the ST1PS03 reaches very high efficiency conversion using just a 2.2 µH inductor and two small capacitors. An advanced design circuitry is developed to minimize the quiescent current. The device embeds a controlled switch accessible from VIN_AUX, to supply a subsystem. Finally, it is available in thin plastic package.

1 Application schematic

Figure 1. **ST1PS03 application schematic**

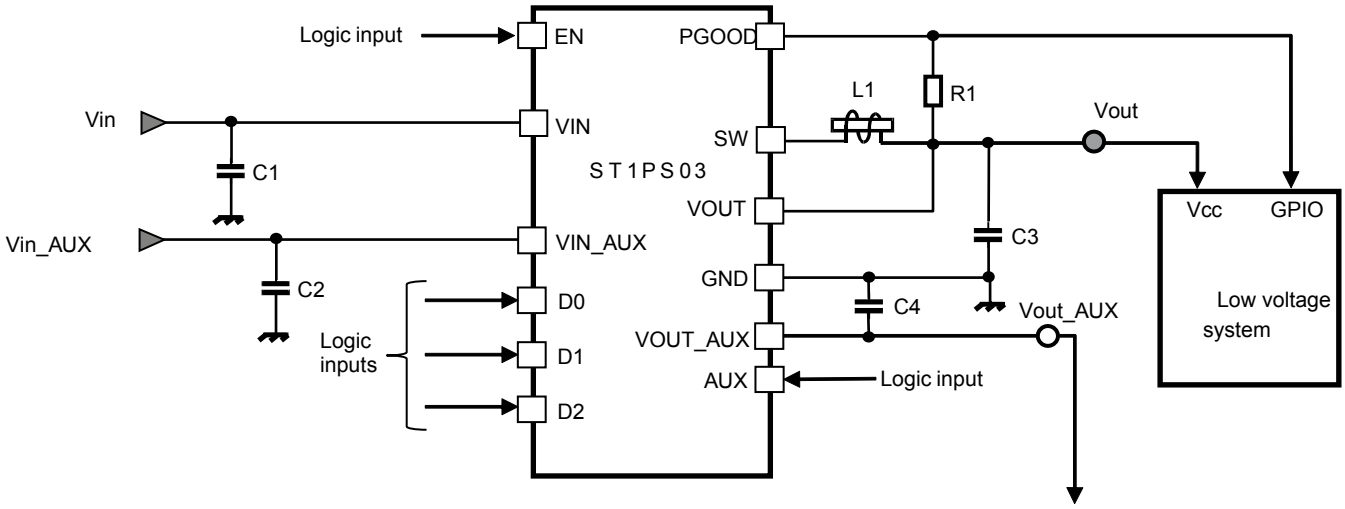


Table 1. **Typical external components**

Component	Description	Value	Size - imperial (metric)
C_1, C_3	Ceramic capacitor with low ESR values	10 µF	0603 (1608)
C_2, C_4	Ceramic capacitor with low ESR values		
L1	Inductor	2.2 µH	0806 (2016)
R_1	Pull-up resistor	1 MΩ	0402 (1005)

2 Pin configuration

Figure 2. **TQFN12 package (top through view)**

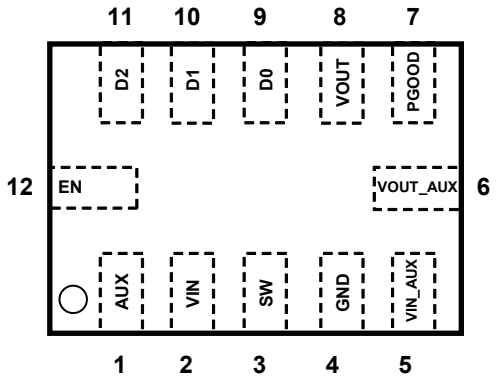


Table 2. **Pin description**

Name	Bump name	Description
AUX	1	Enable for the auxiliary output voltage
VIN	2	Input supply voltage. Bypass this pin to ground with a 10 µF capacitor
SW	3	Switching output. Inductor connection
GND	4	Ground
VIN_AUX	5	Input for auxiliary channel
VOUT_AUX	6	Auxiliary output pin (100 mA max. load)
PGOOD	7	Open drain output. It is in high impedance when the output voltage reaches 97%
VOUT	8	Sense pin used to monitor output voltage
D0	9	Output voltage selection inputs
D1	10	
D2	11	
EN	12	Enable pin. High logic level turns on the IC. VIN threshold referred

3 Functional pin description

GND

Device ground pin.

VIN

Supply voltage. This pin supplies power to the internal analog and digital circuitries when voltage is higher than V_{UVLO}. Bypass this pin to GND with a 10 µF ceramic capacitor. Input capacitor C_1 must be chosen with low ESR to reduce the input voltage ripple.

VIN_AUX

Supply voltage pin for auxiliary channel. This pin supplies internal switch “S3” and must be always ≤ VIN. It is recommended to have VIN_AUX present before setting AUX pin to high, to avoid inrush current on VIN_AUX supply voltage.

Bypass this pin to GND with a ceramic capacitor, see Table 1. Typical external components. Input capacitor C2 must be chosen with low ESR to reduce the input voltage ripple.

SW

Switching output pin. Inductor connection to internal PMOS and NMOS switches.

VOUT

Output voltage sense input pin. It provides the feedback voltage level to the regulation circuitry. 10 µF output capacitor C_3 must be connected close to the pin or through a short trace and should have low ESR to reduce the output voltage ripple.

EN

Enable pin. A logic low level on this pin disables the device. High level enables the device. Do not leave this pin floating.

D0, D1, D2

Output voltage selection pins. See Table 7. Output voltage settings for V_{OUT} selection. Do not leave these pins floating. These pins can be dynamically changed during operation.

PGOOD

Power Good open drain output pin. If used it requires a pull-up resistor to hold a high level signal. High impedance indicates that V_{OUT} is above proper good threshold.

AUX

Load switch selection pins.

When this pin and EN are both set to high, VOUT_AUX output is enabled. If EN low and AUX High VOUT_AUX is disabled. Held to ground if auxiliary output (VOUT_AUX) is not used or if it should be disabled.

VOUT_AUX

Auxiliary output pin. 0.6 Ohm switch connect VIN_AUX to this PIN when enabled. 10 µF output capacitor C4 must be connected close to the pin or through a short trace. This output is controlled from a soft-start circuit and it is not current limited. If unused can be left open.

4 Maximum ratings

Table 3. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{IN}	Power and signal supply voltage	- 0.3 to + 6.5	V
VIN_AUX	Auxiliary input	- 0.3 to + 6.5	V
EN, D0, D1, D2, AUX	Logic input pins	- 0.3 to + 6.5	V
V_{OUT}, SW	Output signal monitoring and switching pins	-0.3 to V_{IN} + 0.3	V
VOUT_AUX	Load switch output pin	- 0.3 to + 6.5	V
PGOOD	Power Good open drain output pin	- 0.3 to + 6.5	V
T_J	Junction temperature	-40 to 125	°C
T_{STG}	Storage temperature	-55 to 150	°C

Note: Absolute maximum ratings are those values beyond which damage to the device may occur. Functional operation under these conditions is not implied

Table 4. Thermal data

Symbol	Parameter	TQFN12	Unit
R_{thJA}	Thermal resistance junction-ambient	75	°C/W

Table 5. Recommended operating conditions

Symbol	Parameter	Min.	Typ.	Max.	Unit
VIN	Input supply voltage	1.8		5.5	V
VIN_AUX	Auxiliary input	0		VIN	V
IOUT_AUX	Auxiliary output current			100	mA

5 Electrical characteristics

C_1 = 10 µF, C_2 = 10 µF, C_3 = 10 µF, C_4 = 10 µF, L1 = 2.2 µH, V_{IN} = 3.6 V, V_{EN} = V_{IN}, V_{OUT} = 1.8 V, T_A = 25 °C unless otherwise specified.

Table 6. Electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
General section						
IQ	Quiescent current	EN = V_{IN}, AUX = GND, device does not switch (V_{OUT} pin voltage > V_{OUT} setting value)	-	500	850	nA
ISD	Shutdown current	EN = GND, shutdown current into V_{IN}	-	10	200	nA
V_{UVLO}	Undervoltage lockout threshold	V_{IN} rising	-	1.63	1.72	V
		V_{IN} falling	1.51	1.57	-	V
		Hysteresis	-	65	-	mV
$V_{th100\%+}$	100% mode leave threshold	V_{IN} rising, 100% mode is disabled with V_{IN} = V_{OUTnom} + $V_{th100\%+}$	-	300	-	mV
$V_{th100\%-}$	100% mode enter threshold	V_{IN} falling, 100% mode is entered with V_{IN} = V_{OUTnom} + $V_{th100\%-}$	-	200	-	
Output voltage						
V_{OUT}	Output voltage range	Output voltages are selected with pins D0, D1, D2	1.6	-	3.3	V
	Output voltage accuracy	V_{IN} = 3.6 V, whole V_{OUT} range, I_{OUT} = 100 mA(1)	-1.5	-	1.5	%
t_{ONmin}	Minimum on-time	V_{IN} = 3.6 V, V_{OUT} = 2.1 V, I_{OUT} = 0 A	-	225	-	ns
t_{OFFmin}	Minimum off-time	V_{IN} = 2.3V	-	50	-	ns
$t_{startupd}$	Start-up delay time	V_{EN} from low to high, V_{IN} = 3.6 V, V_{OUT} = 1.8 V	-	1.7	-	ms
R_{OUTDIS}	Output discharge MOSFET on-resistance	V_{EN} = GND (For AQTR version only), IOUT = -10 mA	-	30	-	Ω
Logic inputs (EN, AUX)						
V_{IL_L1}	Low level input voltage threshold	V_{IN} = 1.8 to 5.5 V	-	-	0.3	V
V_{IH_L1}	High level input voltage threshold		1.1	-	-	
Logic inputs (D0, D1, D2)						
V_{IL_L2}	Low level input voltage threshold	VIN = 3.6 V			0.3	V
V_{IH_L2}	High level input voltage threshold		1.1			
Power switch						
$R_{DS(on)}$	High-side MOSFET on-resistance	V_{IN} = 3.6 V, I_{sw} = 100 mA	-	0.45	0.60	Ω
	Low-side MOSFET on-resistance		-	0.23	0.35	

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I_{LIM}	High-side MOSFET switch current limit	3.6 V ≤ VIN ≤ 5.5 V	500		1150	mA
Power Good output (PGOOD)						
V_{PG_TH}	Power Good threshold voltage	Rising output voltage on V_{OUT} pin, referred to V_{OUT} selected (D0, D1, D2)	95	97.5	-	%
$V_{PG\_TH\_Hy}$		Hysteresis	-4	-3.5	-2.5	
V_{OL}	Low level output voltage	1.8 V ≤ V_{IN} ≤ 5.5 V, E_N = GND, current into PGOOD pin, I_{PGOOD} = 4 mA	-	-	0.23	V
Auxiliary output (VOUT_AUX)						
R_{AUX}	High-side Mosfet on-resistance	IOUT_AUX = 100 mA, AUX = VIN VIN_AUX = 2 V		0.6	0.8	Ω
R_{OUTDIS_AUX}	Low-side Mosfet on-resistance (discharger)	IOUT_AUX = -10 mA, AUX = GND	-	30	50	
tr_aux	Vaux rise time	V_{IN} = 3.6 V VIN_AUX = 1.8V, AUX low to high transition, time to ramp VOUT_AUX from 0 to 95% of VIN_AUX	-	400	850	µs
LK_{AUX}	Leakage from VIN_AUX(1)	VIN = VIN_AUX = 3.3 V, AUX = GND		0.3		nA

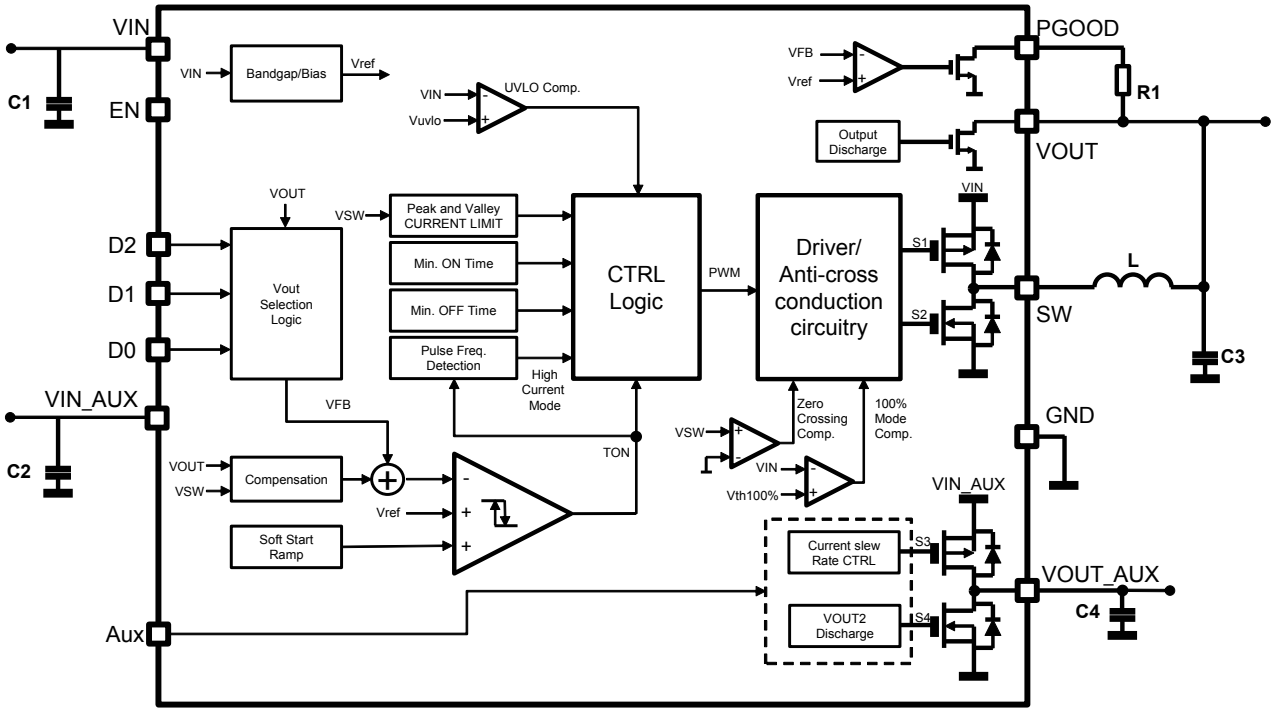
1. *Specified by design – not tested in production.*

Table 7. Output voltage settings

Device	D2	D1	D0	V_{OUT}
ST1PS03	0	0	0	1.8 V
	0	0	1	3.3 V
	0	1	0	2.8 V
	0	1	1	2.7 V
	1	0	0	3.0 V
	1	0	1	2.1 V
	1	1	0	1.6 V
	1	1	1	2.5 V

6 ST1PS03 block diagram

Figure 3. **Block diagram**



7 Operation description

The ST1PS03 is an ultra-low quiescent new generation buck converter. It targets a very small quiescent current consumption (typical 500 nA) and it guarantees high efficiency operation even down to few microampere loads.

It is based on a hysteretic comparator that senses the coil ripple current that is held constant in all operation modes. The device has seamless transition between PFM (pulse frequency modulation) and PWM (pulse width modulation) mode with low ripple and good load transient response.

In order to maintain constant ripple current on the selected coil, the device changes switching frequency, which also depends on input supply voltage. During PWM mode (heavy load), the device operates in continuous conduction up to 400 mA and switching frequency can reach 2 MHz maximum.

7.1 Power save mode

At light load, the device enters automatically power save mode with total current consumption from the input power supply of 500 nA typical. During this condition most of the internal blocks are turned off in order to reach ultra-low power consumption. During this time, the load current is supported by the output capacitor.

7.2 Output voltage

The device allows the output voltage selection without an external resistor divider. Standard digital inputs are used to configure the device to supply a fixed output voltage according to Table 7. Output voltage settings. The V_{OUT} pin must be connected directly and as close as possible to the inductor terminal to obtain the best performance and get the best output voltage regulation. The output voltage can be dynamically changed to implement voltage scaling.

7.3 Output discharge and UVLO

The device embeds a fast output discharge circuitry active when the enable pin is held to ground (EN = GND) or when the input supply voltage reaches the minimum voltage level set by the UVLO protection circuit (undervoltage lock-out protection circuit). The UVLO rising threshold at 1.63 V (typ.) guarantees a proper device supply voltage operation. The output discharge function is available for the ST1PS03AQTR versions.

7.4 Soft-start and current limitation

The device embeds a fixed soft-start circuit active during a limited time period (few ms). This feature allows the inrush current to be minimized from the power supply in case of weak source. During this period internal circuit reduces to 280 mA the typical switch current limit. The ST1PS03 embeds also a current limit on high-side MOSFET to protect the device against overload or short-circuit on the output, during normal operation conditions. When the device enters 100% duty cycle operation condition and an overload (or short-circuit) occurs, the device reacts switching asynchronously between I_{lim} and I_{valley} with a given slope, dependent on L and C_{out}.

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7.5 100% duty cycle operation

The device enters 100% duty cycle operation if the input voltage comes close to the selected output voltage. During this mode, the regulator is turned off and output pin is directly connected to the input pin through the high-side MOSFET. The output voltage follows the input level minus the voltage drop across the internal MOSFET and the inductor. Once the input voltage exceeds the 100% duty cyle leave threshold, the device restarts to switch and regulates the select output voltage again.

7.6 Auxiliary output (VOUT_AUX)

The AUX pin controls VOUT_AUX output. It provides the same regulated voltage level as VIN_AUX input voltage, less drop on the load switch circuitry, when AUX pin and EN tied high. The VOUT_AUX pin allows connecting/ disconnecting the other system load to the output of the ST1PS03.

7.7 Power Good flag

The Power Good comparator monitors the selected V_{OUT} voltage. The open drain output is in high impedance when the V_{OUT} reaches the correct voltage level while it switches to low level when V_{OUT} falls below the normal voltage level.

8 Typical performance characteristics

Figure 4. Efficiency vs. load, V_{OUT} = 1.8 V

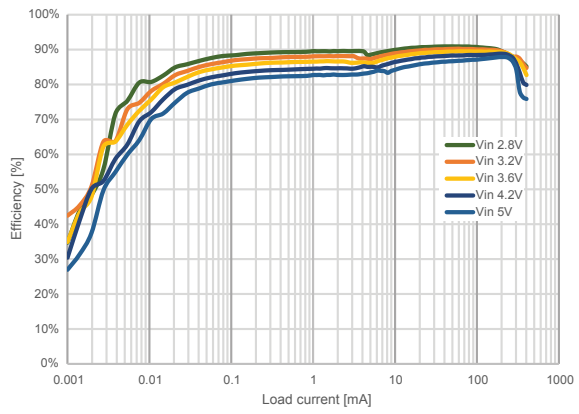


Figure 5. Efficiency vs. V_{IN}, V_{OUT} = 1.8 V

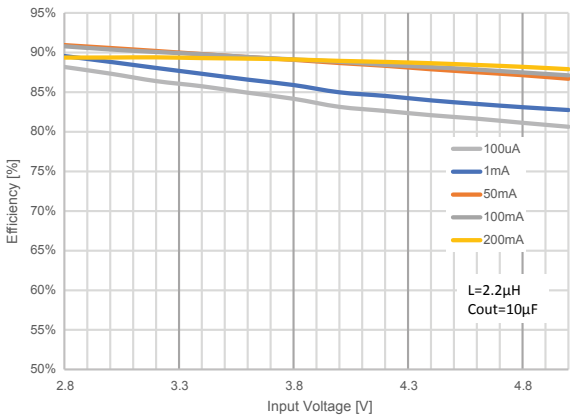


Figure 6. Efficiency vs. load, V_{OUT} = 2.5 V

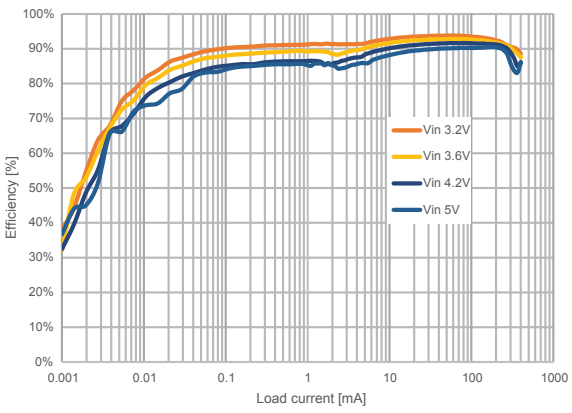


Figure 7. Efficiency vs. V_{IN}, V_{OUT} = 2.5 V

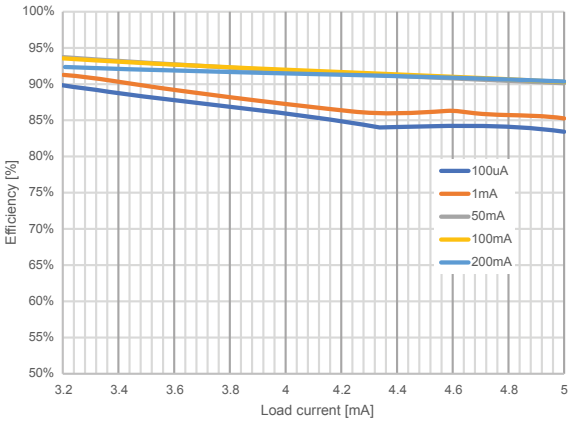


Figure 8. 100% mode, V_{OUT} = 1.8 V, IOUT 100 mA, R_{load} = 18 Ohm, VEN = VIN, AUX = GND

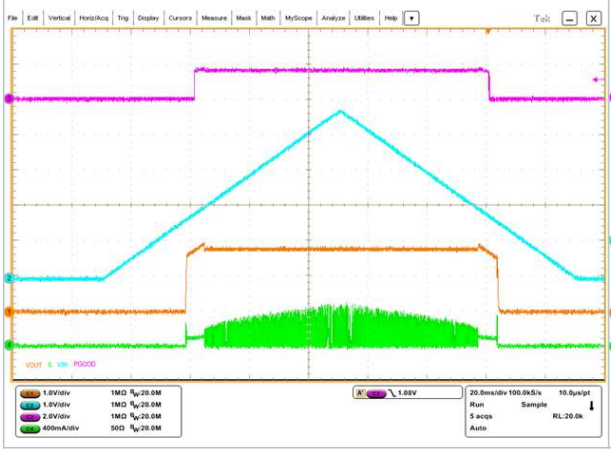


Figure 9. 100% mode, V_{OUT} = 3.3 V, IOUT 100 mA, R_{load} = 33 Ohm, VEN = VIN, AUX = GND

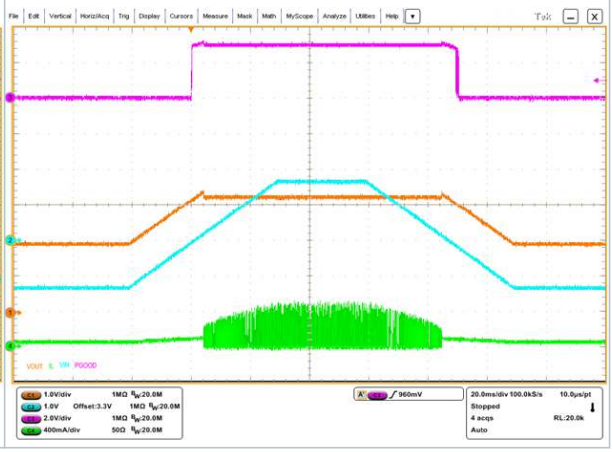


Figure 10. Vin = 3. 6 V, Vout = 1.8 to 3.3 V, R_{load} 33 Ohm, AUX = GND, VIN_AUX = floating

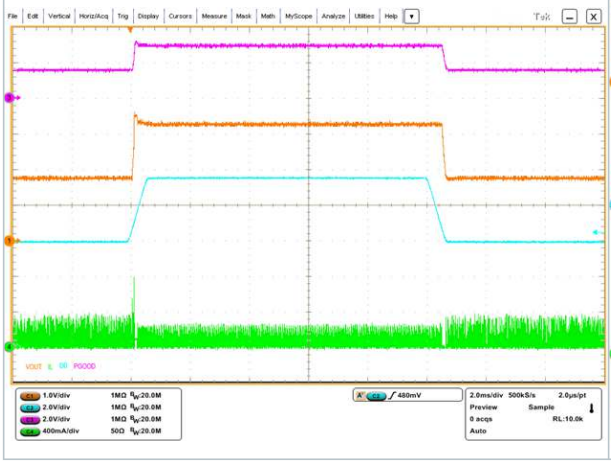


Figure 11. Output ripple, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, IOUT = 10 µA

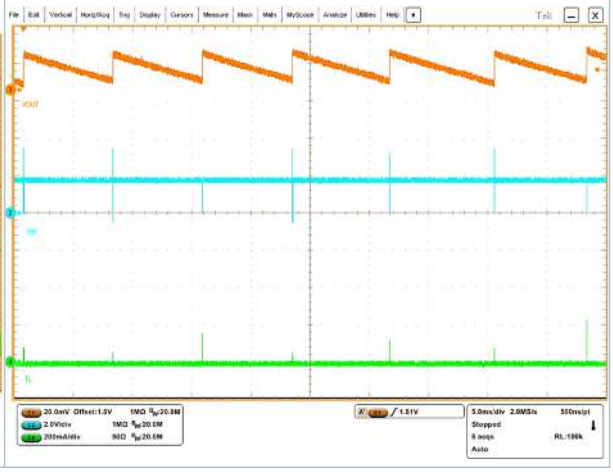


Figure 12. Output ripple, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, IOUT = 1 mA

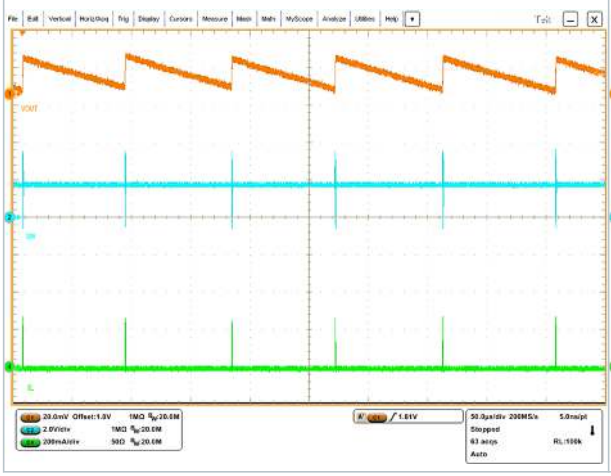


Figure 13. Output ripple, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, IOUT = 50 mA

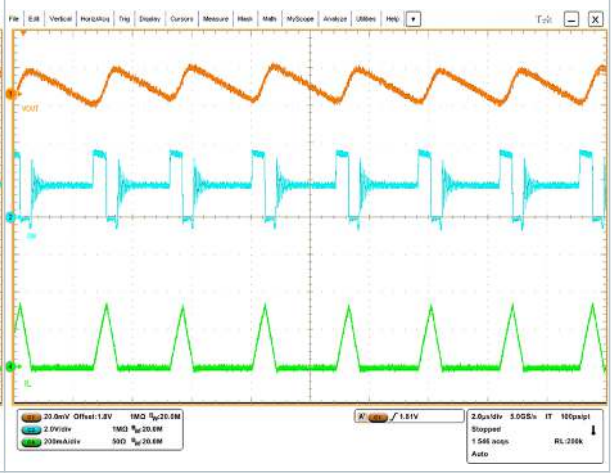


Figure 14. Output ripple, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, IOUT = 150 mA

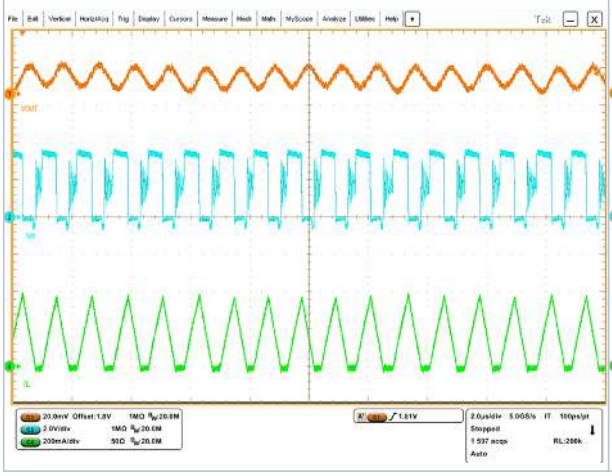


Figure 15. Output ripple, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, IOUT = 250 mA

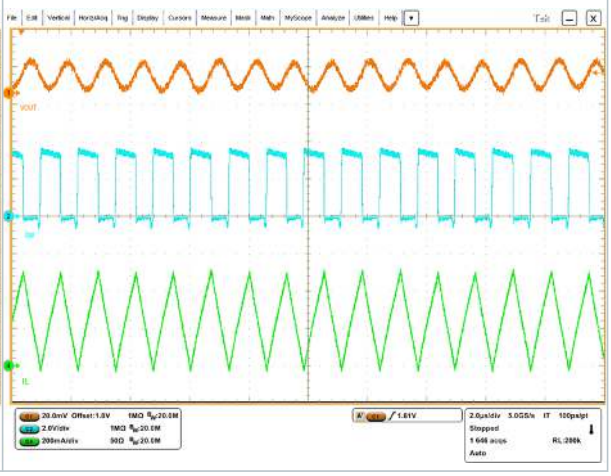


Figure 16. Startup, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, no load

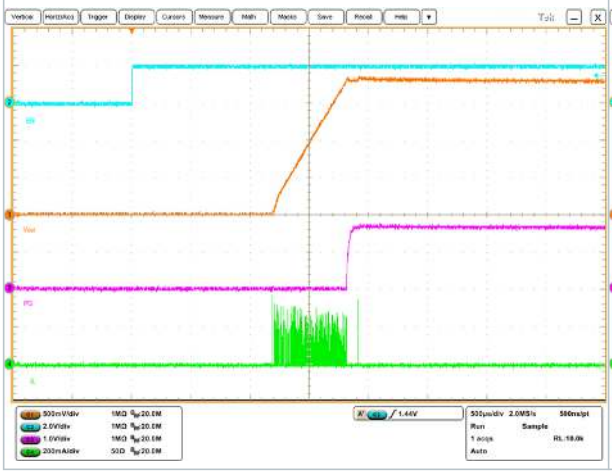


Figure 17. Disable, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, no load

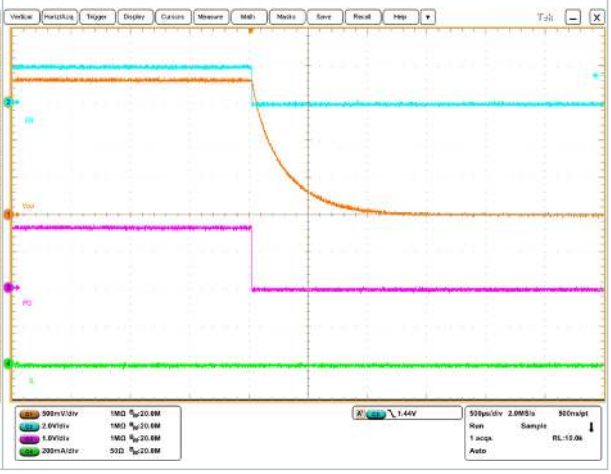


Figure 18. Startup, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, R_{LOAD} = 18 Ohm

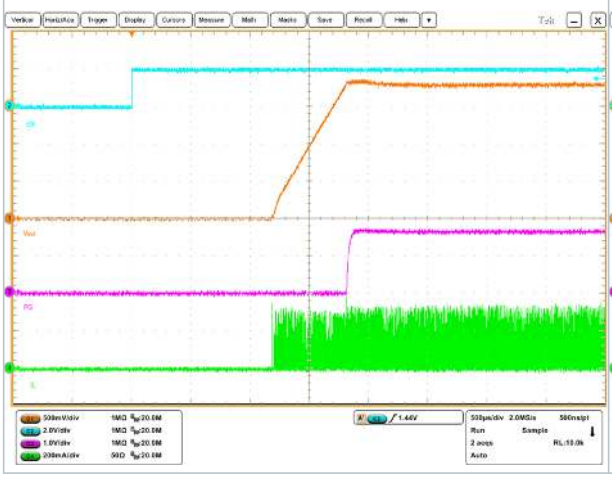


Figure 19. Disable, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, R_{LOAD} = 18 Ohm

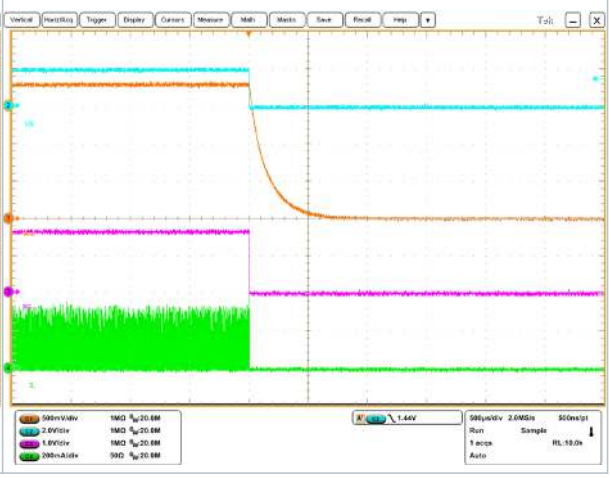


Figure 20. Load transient, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, IOUT = 50 µA to 10 mA

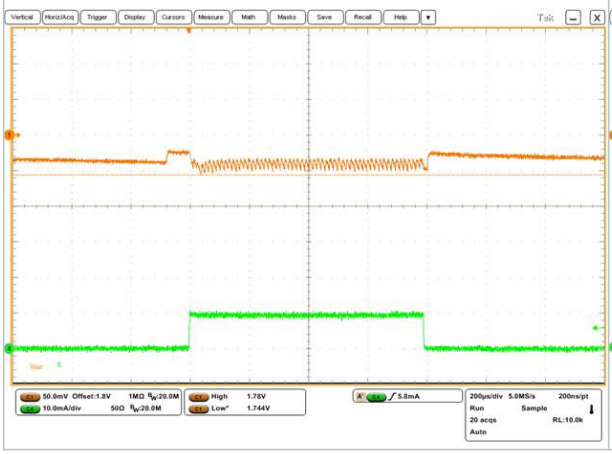


Figure 21. Load transient, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, IOUT = 0 to 100 mA

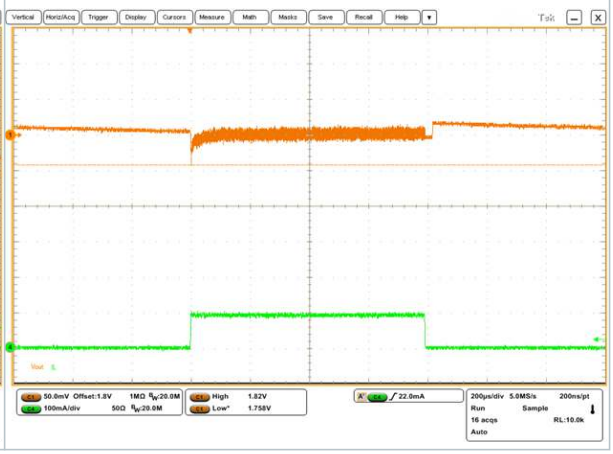


Figure 22. Load transient, V_{IN} = 3.6 V, V_{OUT} = 1.8 V, IOUT = 10 to 100 mA

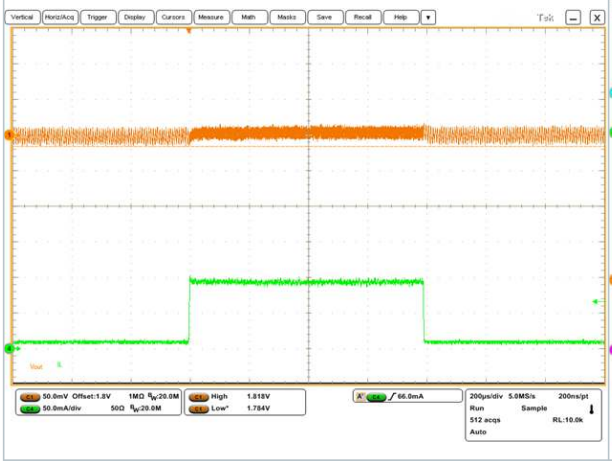


Figure 23. Startup, V_{IN} = 3.6 V, VIN_AUX = 1.8 V, VOUT = 1.8 V, VOUT_AUX = 1.8 V, no load

Figure 24. Disable, V_{IN} = 3.6 V, VIN_AUX = 1.8 V, VOUT = 1.8 V, VOUT_AUX = 1.8 V, no load

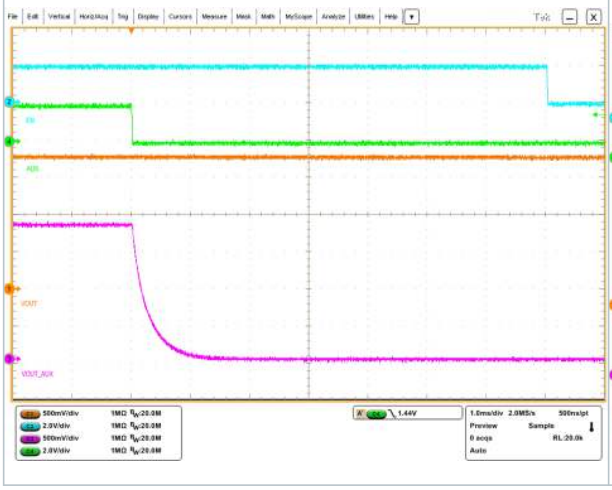


Figure 25. Startup, V_{IN} = 3.6, VIN_AUX = 1.8 V, VOUT = 1.8 V, VOUT_AUX = 1.8 V, R_{load} = 18 Ohm, IOUT = 100 mA

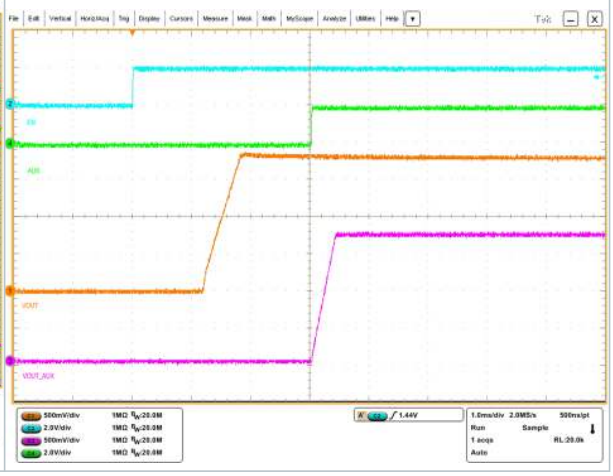


Figure 26. Disable, VIN = 3.6 V, VIN_AUX = 1.8 V, VOUT = 1.8 V, VOUT_AUX = 1.8 V, R_{load} = 18 Ohm, IOUT = 100 mA

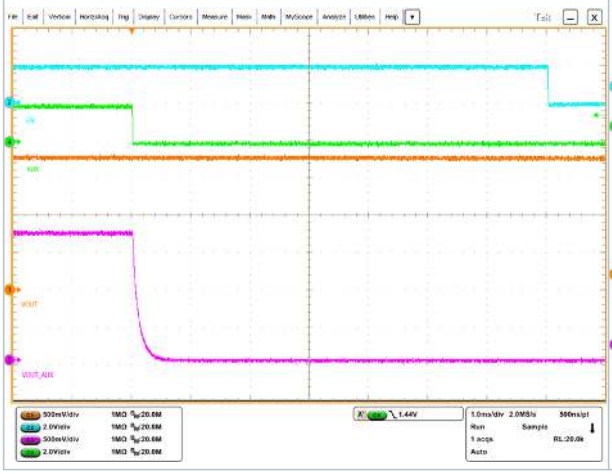


Figure 27. Startup, VIN = 3.6 V, VIN_AUX = 3.3 V, VOUT = 3.3 V, VOUT_AUX = 3.3 V, no load

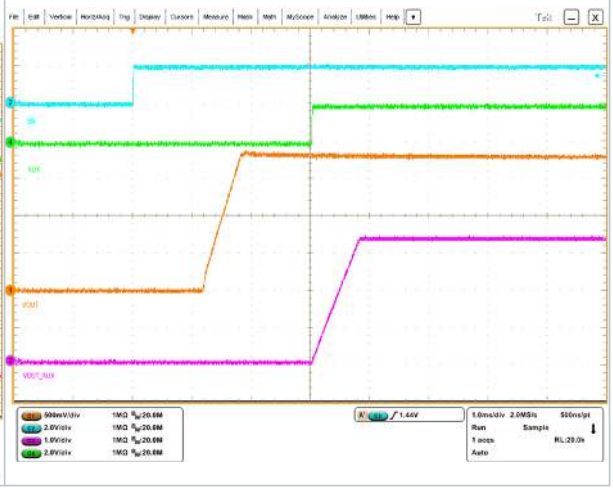
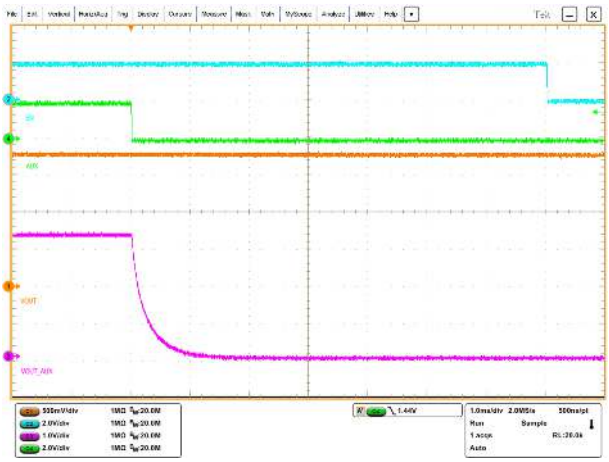


Figure 28. Disable, VIN = 3.6 V, VIN_AUX = 1.8 V, VOUT = 3.3 V, VOUT_AUX = 3.3 V, no load



9 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

9.1 TQFN12 (2.0x1.7x0.55 mm) package information

Figure 29. TQFN12 (2.0x1.7x0.55 mm) package outline

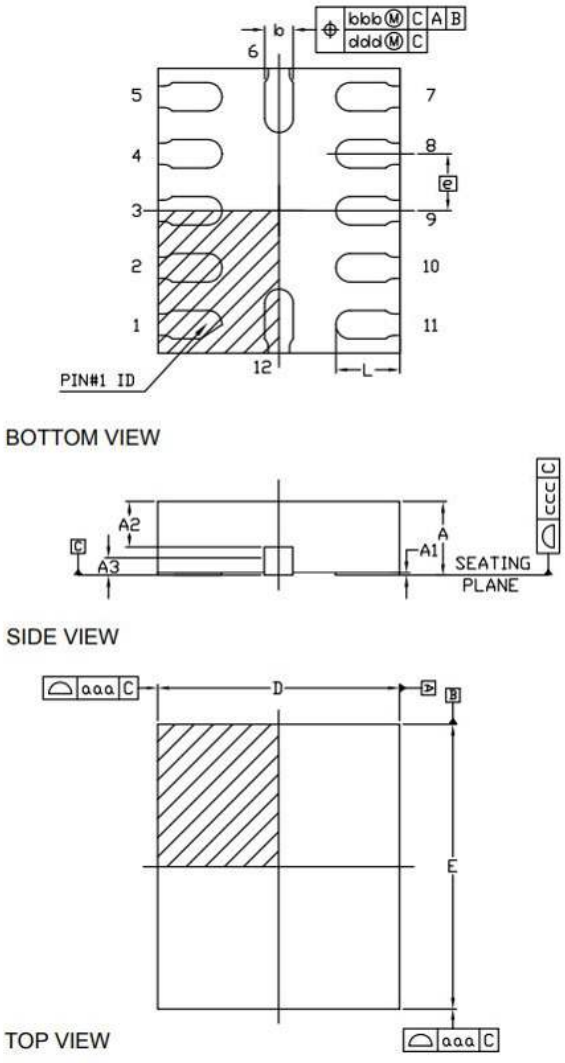
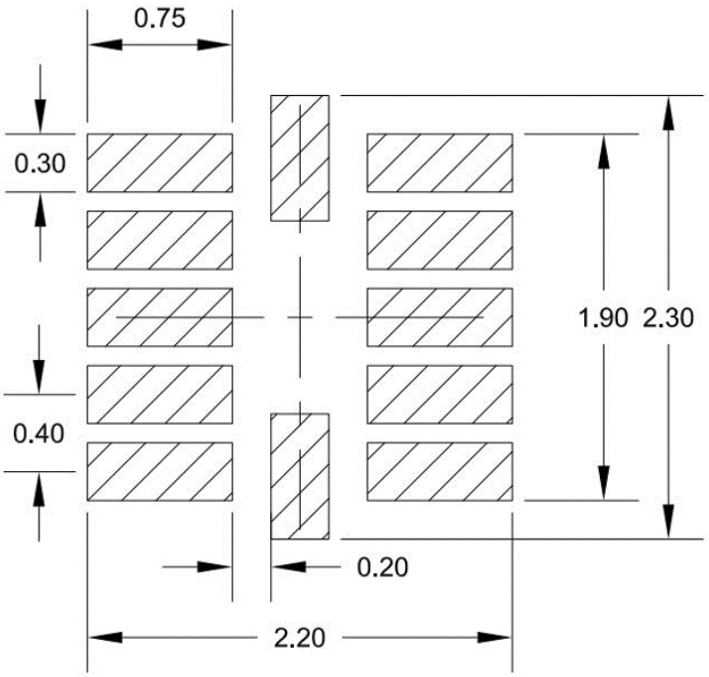


Table 8. **TQFN12 (2.0x1.7x0.55 mm) mechanical data**

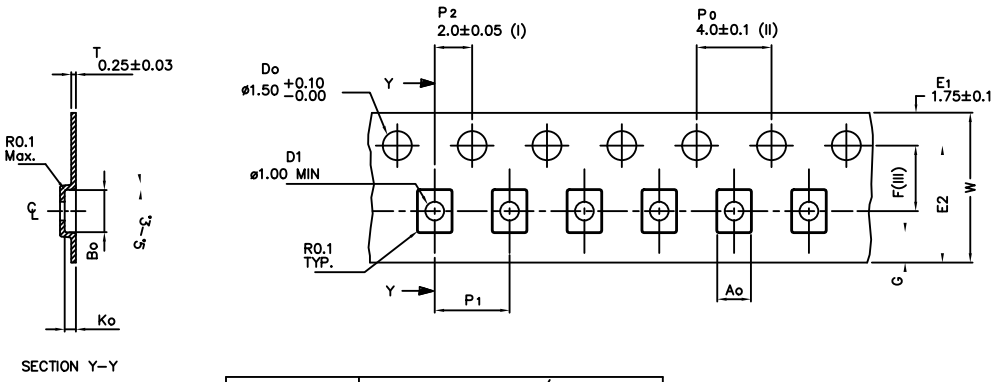
Symbol	Milimeters		
	Min.	Typ.	Max.
A	0.40	0.50	0.55
A1	0.00	0.03	0.05
A2	0.28	0.38	0.48
A3		0.125	
b	0.15	0.20	0.25
D	1.60	1.70	1.80
E	1.90	2.00	2.10
e		0.40	
L	0.35	0.45	0.55
aaa		0.15	
bbb		0.10	
ccc		0.08	
ddd		0.05	
eee		0.10	

Figure 30. **TQFN12 (2.0x1.7x0.55 mm) recommended footprint**



9.2 TQFN12 (2.0x1.70x0.55 mm) packing information

Figure 31. **TQFN12 (2.0x1.70x0.55 mm) carrier tape outline**



Ao	1.80 +/−0.05
Bo	2.25 +/−0.05
Ko	0.60 +/−0.05
F	3.50 +/−0.05
P1	4.00 +/−0.1
D1	1.00 MIN
T	0.25 +/−0.03
G	0.75 MIN.
E2	6.25 MIN.
W	8.00 +0.3/−0.1

Figure 32. **TQFN12 (2.0x1.70x0.55 mm) tape orientation**

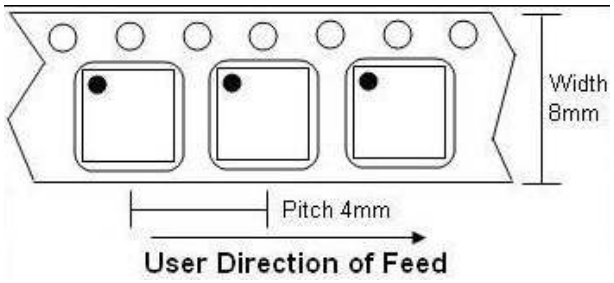
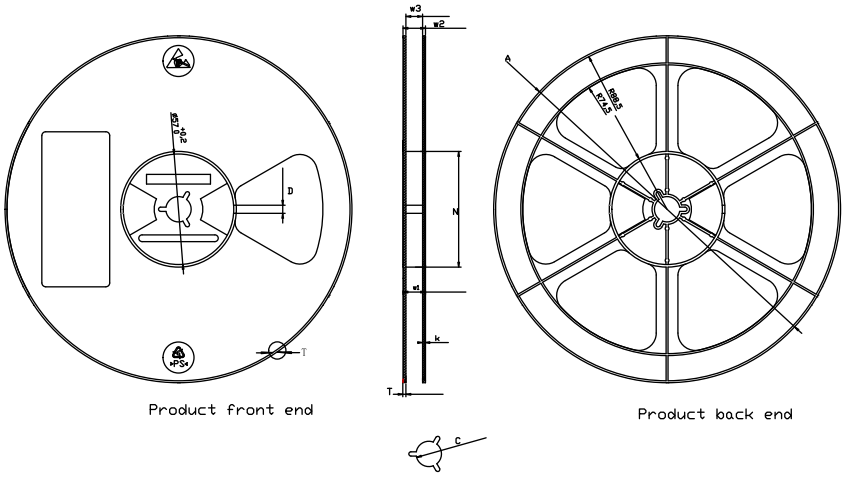


Figure 33. **TQFN12 (2.0x1.70x0.55 mm) reel outline**



TYPE	A	N	C	D	w1	w2	w3	T	k
8MM	ø180±2	ø60±1	13,1±0.2	4,2±0,5	$8,4^{+1}_{-0.2}$	11,6±1	8,75±1	1,5±0,15	1,25+0.1/-0.05

10 Ordering information

Table 9. **Ordering information**

Order codes	Output voltages	Output discharge	Package	Packing
ST1PS03AQTR	1.60 V to 3.3 V	Yes	TQFN12 (2.0x1.7 mm) 400 µm pitch	Tape and reel
ST1PS03A1QTR		No		

Revision history

Table 10. **Document revision history**

Date	Version	Changes
27-Sep-2021	1	Initial release.

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